

WHAT IS CLAIMED IS:

1           1.     A process for combined thermal and catalytic treatment of heavy petroleum in a slurry  
2 phase counterflow reactor, which process comprises:

3                   a)     introducing a liquid feedstock at a top of a reactor vessel to a gas phase  
4 thermal reaction zone and thermally reacting said liquid feedstock;

5                   b)     injecting a gas comprising hydrogen near a bottom of said reactor vessel in  
6 a catalytic reaction zone;

7                   c)     passing said liquid from said gas phase thermal reaction zone to a liquid phase  
8 thermal reaction zone in said reactor vessel below and in communication with said gas-phase  
9 thermal reaction zone and thermally reacting said reacted liquid therein;

10                  d)     passing said reacted liquid from said liquid phase thermal reaction zone to a  
11 catalytic reaction zone below said liquid phase thermal reaction zone and chemically reacting said  
12 reacted liquid therein; and

13                  e)     dispersing said hydrogen through said catalytic reaction zone, through said  
14 liquid phase thermal reaction zone and through said gas-phase zone and thereafter separating said  
15 hydrogen along with gaseous hydrocarbon products from said thermal and chemical reactions.

1           2.     A process for combined thermal and catalytic treatment as set forth in Claim 1  
2 including the additional steps of:

3                   withdrawing heavy unconverted residual product from said bottom of said reactor  
4 vessel;

5 directing at least a portion of said heavy residual product removed to a catalyst  
6 addition system having a buffer tank; and  
7 introducing catalyst to said reactor vessel from said catalyst addition system to said  
8 catalytic reaction zone.

1 3. A process for combined thermal and catalytic treatment as set forth in Claim 1  
2 wherein said hydrogen gas is dispersed by injecting into said reactor vessel at said catalytic reaction  
3 zone and bubbling said hydrogen gas through said vessel.

1 4. A process for combined thermal and catalytic treatment as set forth in Claim 1  
2 wherein said hydrogen gas is hot.

1 5. A process for combined thermal and catalytic treatment as set forth in Claim 1  
2 including the additional step of encouraging mixing of said liquid in said liquid phase thermal  
3 reaction zone through the use of a plurality of vertical baffles.

1 6. A process for combined thermal and catalytic treatment as set forth in Claim 1  
2 including the additional step of filtering said withdrawing hydrogen gas with gaseous hydrogen  
3 product through a filter to remove solids.

1 7. A process for combined thermal and catalytic treatment as set forth in Claim 1  
2 including a liquid level detector to monitor the level of liquid in said liquid phase thermal reaction  
3 zone in said reactor vessel.

4           8.     A process for combined thermal and catalytic treatment as set forth in Claim 1  
5 including the additional, initial step of passing said liquid feedstock in heat exchange with said  
6 withdrawing hydrogen gas and hydrocarbon product to heat said liquid feedstock.

1           9.     A process for combined thermal and catalytic treatment as set forth in Claim 1  
2 wherein said step of introducing liquid feedstock to a top of a reactor vessel is below a porous metal  
3 filter screen.

1           10.    A process for combined thermal and catalytic treatment as set forth in Claim 1  
2 wherein said step of introducing liquid feedstock at said top of said reactor vessel is through a  
3 nozzle.

1           11.    A process for combined thermal and catalytic treatment as set forth in Claim 1  
2 including the additional step of separating said withdrawn hydrogen gas from said gaseous  
3 hydrocarbon product and recirculating through said catalytic zone.

1           12.    A process for combined thermal and catalytic treatment as set forth in Claim 1  
2 including controlling and monitoring pressure by a pressure let down system.

1           13.    A process for combined thermal and catalytic treatment as set forth in Claim 1  
2 wherein pressure in said reactor vessel is maintained at 1500-2000 PSIG and temperature is  
3 maintained at 450°F-850°F.

1           14.     A slurry phase counter flow reactor for combined thermal and catalytic treatment of  
2 heavy petroleum, which reactor comprises:

3                   a reactor vessel having a gas-phase thermal reaction zone, a liquid phase thermal  
4 reaction zone, and a catalytic reaction zone;

5                   a feedstock inlet in communication with said gas-phase thermal reaction zone;

6                   a hydrogen-containing gas inlet in communication with said catalytic reaction zone;

7                   an unconverted liquid and solid recovery outlet in communication with said catalytic  
8 reaction zone; and;

9                   a hydrogen-containing gas and gaseous hydrocarbon product outlet in communication  
10 with said gas-phase thermal reaction zone.

1           15.     A slurry phase counter flow reactor for combined thermal and catalytic treatment  
2 petroleum as set forth in Claim 14 including a catalyst addition system.

1           16.     A slurry phase counter flow reactor for combined thermal and catalytic treatment of  
2 heavy petroleum as set forth in Claim 15 wherein said catalyst addition system includes an inlet in  
3 communication with said liquid bottom product recovery outlet, a pump, a buffer tank, and an outlet  
4 in communication with said catalytic reaction zone of said reactor.

1           17.     A slurry phase counter flow reactor for combined thermal and catalytic treatment of  
2 heavy petroleum as set forth in Claim 14 wherein said hydrogen-containing gas is substantially  
3 hydrogen.

1            18.    A slurry phase counter flow reactor for combined thermal and catalytic treatment of  
2    heavy petroleum as set forth in Claim 14 wherein said hydrogen-containing gas is hot.